COMBINATION TREATMENTS OF POME FRUIT FOR QUARANTINE

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Heat treatments have been used extensively to achieve quarantine security for a variety of tropical and subtropical fruits against fruit flies. Pome fruits, which are typically described as temperature deciduous fruits, have not been thought to withstand such treatments for quarantine purposes. Previous research by scientists in Israel has demonstrated that apples can withstand prestorage heat treatments with an increase in storagability, firmness and a decrease in storage scald. These treatments used a very slow rate of heating, 4°C/Hr, and treated the fruit from 38°C for 4 days to 46°C for 12 hours. We have tested the effect of these treatments on fifth instar codling moth, a quarantine pest in North American grown pome fruits, and found them to be of insufficient intensity and duration to provide adequate quarantine security (Figure 1). However, when the heat treatments are combined with a subsequent cold storage period, then mortalities approach adequate levels (Figure 1).

In an effort to reduce the duration of heat treatments necessary to kill fifth instar codling moth, a forced hot air treatment unit was employed to treat apples, pears and cherries. Heating rates of apples and pears ranged from 10 to 13°C/hr (Table 1), while heating rates of cherries were 60°C/hr (Table 2). We found that both the treatment temperature and the heating rate had a dramatic effect on codling moth mortality (Table 3). When heat treatments were subsequently followed by cold storage, the effect on mortality was increased. While these more rapid heat treatments provided more effective kill of codling moth, it was not without a cost to fruit quality. Only certain cultivars of apples and pears could tolerate the rapid heat treatments, while cherries appeared to tolerate these treatments quite well.

While combination heat and cold treatments provide good control of codling moth, the prolonged exposure of the fruit to high temperatures can cause significant phytotoxicity. In order to reduce the duration of the heat treatment, a controlled atmosphere was added. We found that the addition of a controlled atmosphere to the heat treatment would decrease the total treatment time by at least ¼ to ½ (Table 2). The total heat treatment time could be further reduced by subsequent cold storage.

A mathematical model was developed to describe the effects of temperature and heating rate on fifth instar codling moth mortality in pome fruit (Table 4). The model was tested over a temperature range of 42 to 46°C and heating rates of 4 to 12°C/hr.

Table 1. Lethal heat and combination heat plus cold storage treatment times in which 95% mortality (LT_{95}) of fifth instar codling moth in apples and pears were obtained.

TREATMENT TYPE	TIME TO 42°C	FINAL TEMP	LT_{95} (MINUTES)	
			HEAT	+ COLD
MFA44*	97	42.1	292.0	154.1
MFA46	68	45.4	190.4	90.3
MFA48	56	47.4	120.7	69.0
VFA44	58	44.2	153.8	98.5
VFA46	42	46.3	88.1	52.1
VFA48	32	48.5	66.9	39.9

*MFA = Moist Forced Hot Air; VFA= Vapor Forced Hot Air.

Table 2. Summary of fifth instar codling moth mortality in response to heat and heat plus controlled atmospheres treatments in sweet cherries.

Temperature	Controlled Atmosphere	LT_{99}
45°C	Ambient Air	124 min
45°C	1.0% O_2, 15% CO_2	64 min
47°C	Ambient Air	72 min
47°C	1.0% O_2, 15% CO_2	44 min

Table 3. Comparisons of the effects of treatment type (MFA vs. VFA) on heating rate and fifth instar codling moth mortality in treated apples and pears.

Temperature VFA vs. MFA	% Faster time to 42°C	% Shorter time to LT95
44°C	41	47
46°C	38	54
48°C	42	44

Table 4. Estimation of the time to LT_{95} for treatments at 46°C for fifth instar codling moth treated in apples.

$\log_e (LT_{95}) = 4.900558 + 2.86748 * \log_e(\text{heat rate}) - 1.182104 * [\log_e(\text{heat rate})]^2$
For times at 42°C, multiply by 3.2114
For times at 44°C, multiply by 2.0083

Figure 1. Mortality of fifth instar codling moth treated in apples at a heating rate of 4°C/hr at **A**: 38°C for 4 d; **B**: 42°C for 24 hr; and **C**: 46°C for 12 hr.